SMART TARGET MODEL GENERATOR

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Abstract

This paper describes the Smart Target Model Generator (STMG) tool. The STMG program is sponsored by the Air Force Research Laboratory, Munitions Directorate, Lethality and Vulnerability Branch. The STMG is designed to generate 3D target models for weapon effectiveness analysis. Specifically, it is designed to provide the geometric and physical data needed by the algorithms used for weapons effects assessments. This paper presents the purpose of the STMG, its major capabilities, and its design strategy.

Overview

The Air Force Research Laboratory, Munitions Directorate, Lethality and Vulnerability Branch (AFRL/MNAL) is tasked with providing expeditious weapons effectiveness analyses of weapons concepts against a variety of building targets. Existing target modeling tools do not provide target model generation capabilities adequate for quick turnaround weapons effectiveness assessments. Therefore, a tool is necessary to rapidly produce models of different types of buildings. In response to this need, AFRL/MNAL, under a small business innovative research Phase II contract, is developing a tool that will allow users to rapidly generate 3D models of target scenes. At present, a target scene consists of one or more ground-fixed targets, including hardened underground targets. This tool is called the Smart Target Model Generator (STMG). The STMG is a graphical tool that will be used primarily to quickly generate realistic building models for weapons effectiveness assessments. These models will provide the target data needed to support the various algorithms in the weapons effectiveness assessment tools.

The STMG[1] will allow users to rapidly generate 3D models of ground-fixed targets that include not only the geometric properties of the target but also the material and engineering properties required to perform weapon effects analysis. The STMG will be used in conjunction with various weapon effects models including the Modular Effectiveness/ Vulnerability Assessment Ground-Fixed (MEVA-GF) code[2], the Building Analysis Module code[3], (included in WinJMEM), and the Munitions Effects Assessment (MEA)[4]. Selected STMG algorithms are also being incorporated into AutoDesk's Architectural Desktop[5] as part of a Phase II SBIR funded by the Defense Threat Reduction Agency (DTRA) to support emergency responders.

The STMG can be used to generate individual buildings or groups of buildings. Building models are built in sections and then grouped by function and physical location into facilities. Each building section is divided into levels that encompass a physical part of the building (typically a floor). Groups of facilities constitute a scene. For example, a scene might constitute all or most of the buildings at a military installation. One facility might consist of several physically separate buildings that are used for command and control operations. A particular building might be U-shaped and consist of three rectangular shaped sections that are each one or more stories (i.e., levels) tall.

For each building in a scene, the STMG provides the target data necessary to support weapons effectiveness assessment algorithms. An STMG building model consists of a set of modeling objects. These modeling objects define the geometry of the target components and have sets of attributes that define the engineering and physical properties of the components. Examples of these are the cross section dimensions, strength, and reinforcement description of a reinforced concrete beam, or the dimensions of an I-shaped steel column. In addition, functional relationships between objects are also provided to define information such as the structural connectivity and the room connectivity in a floor plan. Examples of weapons effects models supported by the STMG data include airblast models to calculate shock and gas pressures, structural response and damage, penetration and cratering, fragmentation effects, and models for internal dispersion and

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Abstract

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venting of by-products of weapons of mass destruction.

Component types are predefined and include structural, non-structural, and equipment components. Equipment components are used in the functional model of the target. Structural components include walls, floor and roof slabs, beams, and columns. Non-structural components that are provided include windows, doors, and HVAC ducts, vents, soil, berms, burster slabs, rooms, and external air. Only a limited set of equipment (also called functional or critical) components are pre-defined. These include personnel, HVAC chillers, boilers, cooling towers, and power generation equipment, but additional equipment components can be custom-built by the user.

For critical (functional) components, only a minimal set of component properties is provided. These properties are specific to the component type. User-defined critical components are also provided. With user-defined components, the user may define desired component properties. The component properties must be simple textual, or numeric values. Other component properties can be added relatively easily as needed to support other types of analyses.

<u>Automatic Target Model Generation</u>

Target models can be built automatically using rule-bases based on construction type and building function, or they can be manually generated. The automatic mode is useful when only general and imprecise information about the target is known. In this case, the rule-bases are used to infer the structural layout and physical attributes of the target. In automatic generation mode, the user can import an overhead image of a target scene (e.g., from a UAV), scale the image, and then draw a footprint to specify the target size, as shown in Figure 1. Only rectangular footprints are currently allowed. After drawing the footprint, the user specifies a few target parameters, as needed or desired, such as building height, room layout, or critical component placement, and then presses Execute to generate the building, as shown in Figure 2. Applying this procedure to other buildings in the image, a complete 3D target scene is quickly generated.

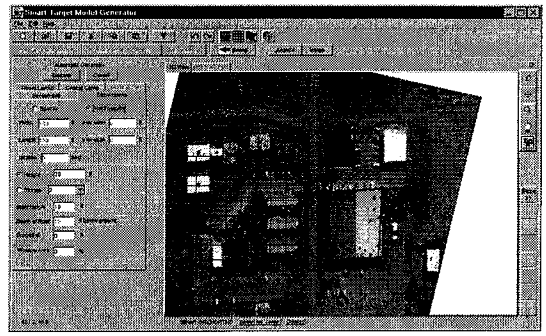

Figure 1. STMG with Overlaid Image

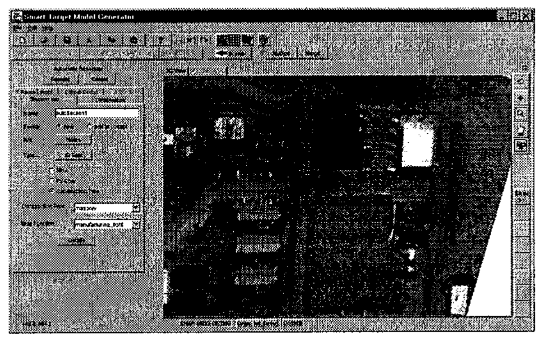

Figure 2. Automatically Generated Target Superimposed on Image

Rule-bases are available for a wide variety of conventional construction (as opposed to hardened and/or buried) building types including framed, wall-bearing, and wall and slab. These rule-bases are used to infer the structural layout and physical attributes of the target so that realistic physical and geometric models of the targets can be generated. Basic engineering design methods and principles as well as design and construction codes and standards are used in the development of these rule-bases. The STMG also provides some algorithms for hardened underground facilities. The following buildings types are currently available but new ones are continually added:

1. Masonry single and multi-story manufacturing
2. Steel-framed office
3. Reinforced concrete framed office
4. Reinforced concrete framed warehouse heavy
5. Pre-cast concrete framed office
6. Steel framed with crane
7. Single-story hardened underground

The rule-bases generally support military, commercial, and industrial building types.

Graphical User Interface

The graphical user interface includes standard CAD capabilities such as:

1. File open, save, import, and export menus
2. A 3D scene viewer that can be used to view an entire scene
3. Standard 2- and 3D viewing tools such as zoom, rotate, and pan
4. An editable grid for building and component placement
5. A 2D view of the target on a floor-by-floor basis for graphical placement and editing of components
6. Component color editor
7. Various components, and properties editing menus specific to each component type

In the automatic generation mode, the grid is designed to assist with the sizing of the entire building using the graphical footprint described earlier. In the editing mode, the grid is designed to aid the placement of structural and equipment components. The user can adjust the grid size and spacing. Variable spacing in both the X and Y direction is provided.

Default component properties are automatically assigned but these can be changed using the component property menus. Standard construction material types such as steel, brick, drywall, concrete, soil, glass, and wood, are provided. Material properties that are required for weapon effects analysis are provided. Material properties are based on the material type, and can be adjusted using the user interface.

Manual Target Creation and Editing

When more detailed and precise information about the target is available models can be generated using the manual mode. In this case, models are either built from scratch or by editing an existing model.

In the manual or editing modes, the 2D editor displays the selected building level (floor) from a top view. A 3D view, which shows views from the top, side, and right, can also be selected.

Components can be placed individually using a point-and-click method, or in groups using a semi-automatic placement method.

The grid is used for semi-automatic placement of structural and non-structural building components. In this manner, entire sets of selected components can be placed on the grid points using pre-defined algorithms. The size and spacing of the grid can be adjusted and irregular grid patterns can also be used. Figure 3 shows a scanned blueprint that has been overlaid on the structural grid. In Figure 4, the beams and floors have been automatically placed on the grid. Both equipment and structural components can be placed using this method, although this was designed primarily to place structural components.

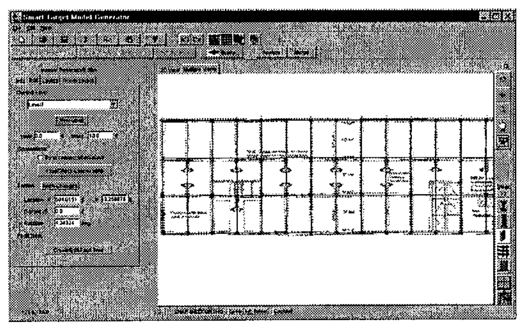

Figure 3. 2D Editor with Image Overlay

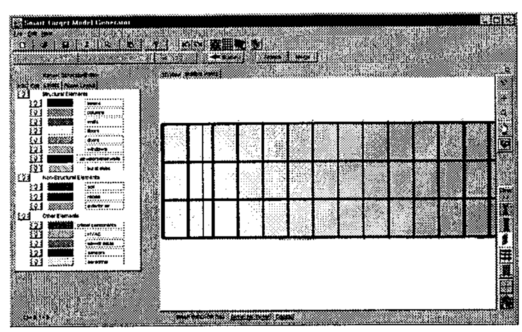

Figure 4. Semi-automated Component Placement

In the fully manual mode, individual components are placed by selecting a component type and using the mouse to place the component on the editor. Figure 5 shows the 2D editor with critical components that have been placed using the toolbar on the far lower right. Once equipment components have been placed, the user can manually generate a functional fault tree for the facility.

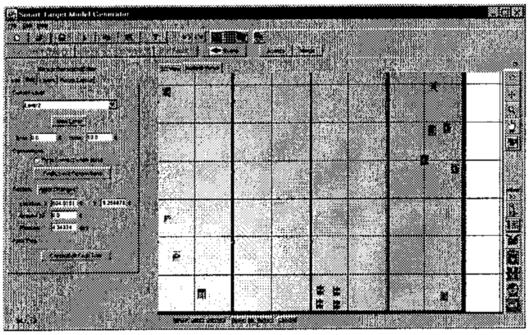

Figure 5. 2D Editor with Manual Component Placement

STMG Design

The STMG can be incorporated in whole or in part into other tools. It is designed in an object-oriented manner and consists of two main parts. The user interface is developed in JAVA and uses the Java Native Interface (JNI) to communicate with the architectural portion of the code, which is developed in C++. The JNI is a method for interfacing Java and C++ code that allows functions in one language to call functions developed in the other language and to pass parameters between them. The C++ portion of the STMG can be distributed separately as a DLL or as a standalone executable without a user interface. This standalone executable can be used to run the automatic generation portion of the code in batch mode. By using the DLL, the STMG can be incorporated into other tools that only require automatic target generation with a minimal user interface. The simple user interface may be developed in another language or development environment such as Visual C++, Qt, or Tcl/Tk.

At compile time or run time, depending on the customer's requirements, the STMG is designed to be able to use either Spatial's ACIS 3D geometry modeler or the simplified Applied Research Associates (ARA) geometry modeler. The ACIS version of the code will allow significantly more sophisticated geometry modeling including arbitrary shaped components, wedge-shaped, arch-shaped, spherical, cylindrical, and box-shaped components. The simplified geometry model allows only cylindrical or box-shaped components.

The STMG is designed in an object-oriented manner. The target model is composed of objects in a hierarchy, where the highest level is the scene, and the lowest level are the component properties. Figure 6 shows the object structure of the scene.

The STMG output consists of an object-oriented ASCII file that contains the scene description and one or more geometry files. The file format is called the target description language (TDL). The TDL file is a tagged XML-like file that contains a description of the entire scene from the highest object to the lowest. The geometry file formats vary depending on the geometry model used and the user's selection. The standard geometry file is an ACIS "sat" file. Other formats include: Ballistic Research Laboratory Computed Aided Design (BRLCAD)[6]'s mged, Virtual Reality Modeling Language (VRML), and an STMG specific ASCII geometry specification format. An Open Flight formatted file is currently being developed.

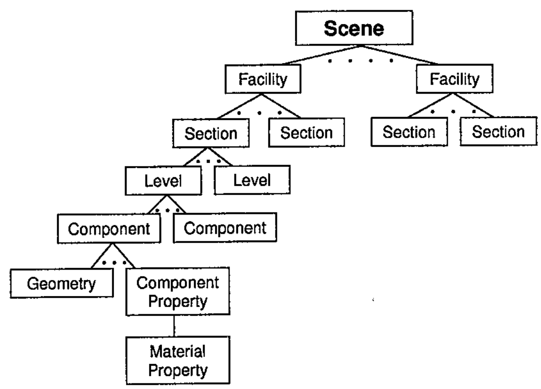

Figure 6. Object Structure of a Scene

Summary

The STMG provides users with a method of rapidly generating 3D ground-fixed target models for conventional and Weapons of Mass Destruction (WMD) weapon effects analysis. It also allows for generation of multiple buildings and functional fault trees for each facility. The STMG can be expanded to add new component types or component properties as needed to support other types of analyses, as well, and can easily be integrated into other tools.

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